HOW TO USE THE ANALOG RESOURCES

Each active SEM module contains an Module Electronics Unit (MEU). This is the power control and data acquisition system for the module experiment. The MEU has a total of 16 analog channels. The microcontroller in the MEU can sample any channel and record the data to the Electrically Erasable Read-Only Memory (EEPROM) while running a timeline. Additionally the Ground Module Electronics Unit (GMEU) can display data to a computer screen while using the diagnostic mode.

With the exception of thermistors, most analog signals will require some sort of a circuit in order to connect to the MEU. This guide contains the essential information to successfully use the SEM analog data channels. This guide is not intended to be a comprehensive design guide. This information applies equally to the MEU and the GMEU.

HOW TO USE THE ANALOG RESOURCES: MODULE ELECTRONICS UNIT (MEU) ANALOG INTERFACES

The MEU provides three experimenter thermistor inputs, six experimenter analog inputs, and five MEU system signals.(See Table 2.1 below.) This section describes the analog resources available to the experimenter.

User Analog Inputs

There are a total of nine analog inputs available for experimenters to connect to. Three of these are designed for thermistors only. Thermistors are covered in detail in Section 5.0. All the experimenter analog inputs are designed for an input Voltage ranging from 0 to +5 Volts Direct Current (VDC). Input Voltages greater than +5 VDC will let the smoke out of the converter. There is no signal conditioning on the MEU.

Additional Data

There are five MEU system analog signals that can be measured. The MEU can measure the SEM battery Voltage, MEU +5 Volts (V) Sensor Power (+5 V precision reference), MEU thermistor, MEU +5 V power supply, and the experiment current. The experiment current has an accuracy of 10%. It is most useful in development and testing of an experiment.

Sensor Power

Sensors may be powered with the +5 VDC Sensor Power. This +5 V supply is limited to a maximum current of 10 Milliampere (mA). It is intended for resistive type loads, such as thermistors. It is not designed to power signal conditioning circuits.

Analog Grounds

There are separate grounds for the thermistors and the analog inputs. The thermistors are required to use the corresponding thermistor grounds. All the general purpose analog signals should use the analog ground. The only exception is when an op-amp or other active signal conditioning circuit is used. In that case do not use the signal ground. The analog signal will then be referenced to the power ground of the active circuit. This might induce some noise in the analog signal, but is precludes ground loops. Ground loops should always be avoided.

Sampling Rates

A total of nine sampling rates are available. See Table 2.2 below. Each sample will occupied two bytes of memory in the MEU Electrically Erasable Programmable Read-Only Memory (EEPROM). The system is designed to measure discrete Voltages and not sample waveform shapes. Table 2.1 - MEU Analog Resources

Table 2.1: MEU Analog Resources

Channel (Dec)	Channel (HEX)	ANALOG Channels	Analog Signal Pin Numbers	Analog Return Pin Numbers
0	0	Experiment Thermistor #1	11	30
1	1	Experiment Thermistor #2	12	31
2	2	Experiment Thermistor #3	13	32
3	3	Experiment Analog #1 (0 to +5 V)	14	33
4	4	Experiment Analog #2 (0 to +5 V)	15	33
5	5	Experiment Analog #3 (0 to +5 V)	16	33
6	6	Experiment Analog #4 (0 to +5 V)	17	33
7	7	Experiment Analog #5 (0 to +5 V)	18	33
8	8	Experiment Analog #6 (0 to +5 V)	19	33
9	9	Not Used (Connected to ground)	-	-
10	A	Not Used (Connected to ground)	-	-
11	B	Experiment Current	Internal	-
12	C	+12V Monitor (SEM Battery)	Internal	-
13	D	+5V MEU Power Supply	Internal	-
14	E	+5V Sensor Power (10 ma max.)	35	33
15	F	MEU Thermistor (YSI 44006)	Internal	-

Table 2.2: MEU Analog Sampling Rates

Rate Number	Rate Identification	Description	Samples/Hour
0	ZERO	No Sampling	0
1	ONCE	Sample Once	-
2	10 MIN	Sample Every 10 Minutes	6
3	5 MIN	Sample Every 5 Minutes	12
4	1 MIN	Sample Every 1 Minutes	60
5	10 SEC	Sample Every 10 Seconds	360
6	5 SEC	Sample Every 10 Seconds	720
7	1 SEC	Sample Every 10 Seconds	3600
8	0.2 SEC	Sample Every 10 Seconds	18000

HOW TO USE THE ANALOG RESOURCES: ANALOG INTERFACING 101

This sections covers some the basic design considerations for developing a circuit to interface to the SEM analog inputs. Thermistor inputs are covered separately in the Thermistor Section

The Module Electronics Unit (MEU) analog/digital (A/D) converter can be used to measure just about anything. However, not all analog signals that may be in an experiment are directly compatible with the MEU A/D converter. The converter can only handle an input Voltage range of 0 to +5 Volts (V) Direct Current (VDC). It is often necessary to design circuits that will bring the signal to be measured within the range of the converter. These signal conditioning circuits effectively re-scale the raw analog signal. However, some more sophisticated circuits can, for example, perform such things as frequency to Voltage conversions, which allows the system to measure frequency.

The most important design consideration is to be certain that MEU input Voltage levels are not exceeded. The analog inputs have a maximum range of 0 to +5 VDC. When developing a conditioning circuit, keep in mind what the worst case conditions. For example the circuit in Figure 3.1 will have an output of 0 to +5 VDC with an input of 0 to +16 VDC. So are long as it is impossible for the circuit to get 16 VDC it will do just fine. However, if the input were to exceed +16 VDC (due to a failure) then there would be a problem.

Clamping Diodes

A protection feature for the MEU that is recommended, but not required, is a clamping diode. A clamping diode is a zener diode that turn on when sufficient Voltage is across its leads. Zener diode come in all different Voltages. For this application a 5 V zener diode should be used. The diode should be connected as shown in Figure 3.1 and 3.2. If for some reason the Voltage into the MEU should exceed +5 VDC the diode would turn on and prevent the high Voltage from getting to the A/D converter.

Bypass Capacitors

The accuracy of a measurement by the A/D converter can be degraded by noise in the system. Noise can originate from many sources. A common example of a noise source is a Direct Current (DC) motor that uses brushes. The easiest way to reduce noise influences is by using a capacitor across the analog signal to ground (be sure it the correct ground or return). Generally the capacitor value should range from 0.01 to 100 Fahrenheit (F). Be sure the Voltage rating of the capacitor is at least 50 VDC.

Voltage Divider

Active Signal Conditioning

The figure below show how an active signal conditioning circuit should be connected to the MEU. Some important points are that the active circuit's power return (circuit ground) is not connected to the analog signal ground. As mentioned Section 2.3, this eliminated ground loops. Power for the active circuit can be supplied by one of the +12 VDC power channels, or through a Voltage regulator that is connected power channel.

HOW TO USE THE ANALOG RESOURCES: INTERPRETING ANALOG MEASUREMENTS

Module Electronics Unit (MEU) Analog/Digital (A/D) Converter

The MEU has a 12-bit analog-to-digital (A/D) converter (MAX191) which measures analog data. The A/D converter can only accept input Voltages ranging from 0 to +5 VDC. The microcontroller in the MEU records the A/D's measurement in binary on the Electrically Erasable Programmable Read-Only Memory (EEPROM) according to the experiment timeline. The data is stored in two bytes, with the most significant byte containing the channel number (first four bits) and the first four bits of data. The second byte contain the last eight bits of the 12-bit measurement. For purposes of this discussion the binary data will be represented in hexadecimal. The digital measurement ranges from 000h (hexadecimal) to FFFh (or 0 to 4095 in decimal). This means that the five volt span of the converter is divided up into 0.001 Volt steps.

Resolution and Accuracy
To be supplied.

Data Conversion
To be supplied.

Formulas for MEU
To be supplied.

Chart
To be supplied.

HOW TO USE THE ANALOG RESOURCES: CALIBRATION
Calibration using the Ground Module Electronics Unit (GMEU)
(To be supplied)

HOW TO USE THE ANALOG RESOURCES: THERMISTORS
The Module Electronics Unit (MEU) provides three analog channels designed to support thermistors. Thermistors are devices that change electrical resistance as temperature changes. The resistance usually changes exponentially with temperature. Most thermistors have an operating range of about -30 Celsius (C) to +120 C.

Thermistor Data
The MEU measure the temperature and comes up with a 12-bit binary number. As discussed above, over a 0 to +5 Volt (V) range, it can measure raw temperature data to within 0.001 V (or 1 megavolt (mV)). Using a YSI 44006 thermistor, this translates into an resolution of about 0.04 C. In practice there tends to be some noise in the system that bring the accuracy of a measurement to about 0.5 degree Celsius. Since the thermistor curve is not linear, the accuracy decreases at the extremes. Figure 6.1 show a typical thermistor curve. The data is in decimal for 0 to 4096 (12-bit data). Additional information on the YSI 44006 thermistor is located in Appendices A and B.

YSI 44006 Thermistor Curve

Hooking up Thermistors
Thermistors can be hooked up directly to the thermistor input and corresponding thermistor return. (See Figure) The noise filtering capacitor (C1 in Figure) is optional. The recommended thermistor to use is a YSI 44006 (10 Kelvin (K)) @ 25. This is the one that is used on the MEU. Other thermistors may be used, but a new thermistor data curve will need to be generated by the experimenter.

Thermistor Circuit for Thermistor Inputs
Additional thermistors can be added using the general purpose analog inputs and the +5 Volt (V) Sensor Power. Use the circuit in the above figure. This circuit must be referenced to the Analog Signal Ground. For best accuracy use a 10K Ohm, 1/4 Watt, 1% tolerance resistor. Capacitor C1 is optional, and a YSI 44006 thermistor is recommended. Other type of resistive transducers can use this type of circuit.

Thermistor Circuit for Experimenter Analog Inputs

Installing Thermistors

To be provided.

HOW TO USE THE ANALOG RESOURCES: ANALOG INTERFACE CHECKLIST

The Analog Interface Check list is designed to help ensure mission success and protect the Space Experiment Module (SEM) flight hardware. It is recommended that all analog channels be checked against this list. This is not a requirement, and not all items necessarily apply.

1) Is the minimum Voltage at Ground Module Electronics Unit (GMEU) analog input is not below 0 Volts Direct Current (VDC)?
Measured: _______VDC
2) Is the maximum Voltage at GMEU analog input, under worst case conditions, always below +5 VDC?
Measured: _______VDC
3) Have the conditioning circuit Voltage limits been tested? Verified: _____________
4) Is a clamping diode (5V zener) placed across analog channel input (optional)?
Verified: _____________
5) Is the diode installed correctly, with the band on the +V side? Verified: _____________
6) Is a bypass capacitor (0.1 µF) placed across analog channel input (optional)?
Verified: _____________
7)Is a bypass capacitor (0.1 µF) placed across conditioning circuit input (optional)?
Verified: _____________
8) Was the analog circuit tested using a volt meter before connecting to GMEU?
Verified: _____________
9) Sample readings using GMEU diagnostic mode and perform calculations to verify that the hexadecimal data is agrees with expected results. Verified: _____________
10) Perform calibration if necessary, following steps described in Section 4.0. Verified: _____________
Are the thermistors connected to the corresponding thermistor returns? Verified: _____________

HOW TO USE THE ANALOG RESOURCES: THERMISTOR FORMULAS

These formulas are for the YSI 44006 thermistor:

R = resistance in Ohms
T = temperature in Kelvin

Constants:
a = 0.0010295
b = 0.0002391
c = 1.568E-7

Have T want R:
R = e exp[(beta - (alpha/2))^(1/3) - (beta + (alpha/2))^(1/3)]
where alpha = (a - (1/T))/c
and beta = [(b/3*c)^3 + (alpha^2)/4]^(1/2)

Have R want T:
T = 1/[a + b*ln(R) + c*(ln(R))^3]

HOW TO USE THE ANALOG RESOURCES: THERMISTOR CIRCUIT ANALYSIS

By: Ken McCaughey /CTA Inc.
File: sem_temp.mcd
Date: 24-July-96 Rev.: A

NOTE: This analysis is based on the thermistor analysis developed for the SPRE experiment (SPRE-ANYS-010).

THERMISTOR SENSOR FORMULA

YSI-44006 temperature vs. resistance. R is in Ohms and T in degrees Celsius.:
Note: Formula provided by YSI Inc.
Resistance values at selected temperatures are in degrees Celsius:

THERMISTOR CIRCUIT ANALYSIS

Thermistor circuit:
RT = thermistor (10K Ohm @ 25 degree Celsius)
Circuit analysis equation with component values:
Various data points:
@ -30 degree Celsius @ 0 degree Celsius @ +25 degree Celsius @ +50 degree Celsius @ +100 degree Celsius
Power dissipation in thermistor:
Maximum Voltage spread over -30 degree Celsius to +100 degree Celsius:
Raw data calculation:
Number of data bits.

TEMPERATURE VS. RAW DATA

TEMPERATURE VS. OUTPUT Voltage